CHAPTER 6

SCOUR

6.01 Purpose

The National Bridge Inspection Standards (NBIS) require each state to identify bridges that are scour critical, and to prepare a plan of action to monitor known and potential deficiencies in accordance with the plan. This process may be divided into two overall categories; the proper coding of Item 113, and managing bridges for scour vulnerability. Coding of Item 113 is determined through one or more analyses to determine whether the structure is susceptible to scour, and may be infrequently updated when conditions contrary to the assigned value are observed or scour countermeasures are installed. The managing of scour critical bridges is a recurrent effort that must be completed throughout the life of the structure. This chapter describes the minimum requirements and monitoring processes that must be adhered to for NBIS compliance. For additional information review Chapter 13 of the FHWA *Bridge Inspector's Reference Manual* (BIRM).

6.02 Responsibilities

Responsibility for coding Item 113 does not follow identical processes for MDOT and local agency owned bridges. For MDOT owned bridges, the coding determination is a collaborative effort performed between the Bureau of Development Hydraulics Unit and the Region Bridge Engineer (bridge owner). For local agency owned bridges, the bridge owner is responsible for performing the coding. Additional information regarding this practice is described in Coding and Managing Bridges for Scour Vulnerability found at MDOT's Bridge Operations Manual & Guides page.

The bridge owner is also responsible for ensuring that each bridge over water has a scour vulnerability evaluation in the bridge file. If the evaluation indicates that the bridge is scour critical, then the bridge owner shall be responsible for creating and maintaining an up-to-date Scour Plan of Action (POA) until the bridge is replaced or other measures are installed. Ensuring consistent monitoring in accordance with the POA is also the responsibility of the bridge owner.

The bridge owner shall ensure that the POA is reviewed during flood events and determine whether monitoring is required. When monitoring is necessary, and the work will be performed by an individual other than the bridge owner, the POA must be assigned in MiB^{RIDG}E. This will allow for the inspector to document the findings for the High Flow Event or Scour Action Inspection Report that is added within the POA.

6.02.01 FHWA Metric #18 Inspection Procedures – Scour Critical Bridges

In compliance with NBIS, the bridge owner shall ensure that all bridges over water have the following;

- Evaluation of scour vulnerability

- POA prepared and implemented to evaluate known and potential deficiencies for scour critical bridges
- Methods and procedures to monitor scour critical bridges in accordance with the POA.

On an annual basis, FHWA reviews the entire Michigan bridge inventory and compiles a list of structures where Item 113 is coded 3 or less, U, 6, or null and provides MDOT with an Assessment Reporting Tool (ART) report. The results are then reviewed by MDOT and a response is provided for each of the identified deficiencies. The majority of the defects identified are related to bridges that were constructed within the previous 90 or 180 days that the report was generated, but when monitoring is not documented within MiB[RIDG]E each individual agency must be contacted for an explanation so a formal response may be provided.

In addition to the ART reports generated from the database query, FHWA also performs intermediate or in-depth assessments during randomly selected file and field reviews to verify that scour monitoring occurred in accordance with the POA. All scour critical bridges located over a watercourse that experienced flooding during the previous year should have a High Flow Event and/or Scour Action Inspection Report to document that monitoring and follow-up occurred.

In order to maintain FHWA compliance, bridge owners must continue to update inventory coding, develop a comprehensive POA, and perform documented monitoring as-needed. Failure to abide by the FHWA requirements may result in a non-compliance finding and jeopardize the disbursement of funding to the state and/or individual agencies involved.

6.03 Scour Analysis

All bridges over water require an assessment of the scour vulnerability to be performed. This evaluation may have occurred prior to construction depending on the year of design. During 1992 requirements were incorporated in the American Association of State Highway and Transportation Officials (AASHTO) *Standard Specifications for Highway Bridges* manual for hydraulic studies to be completed during the preliminary design phase to ensure that the bridge could withstand the effects of scour. Structures built before or during the timeframe that the standard was developed were not required to be evaluated for scour during the design phase.

The minimum documentation that must be in the bridge file includes a completed Level One analysis, or for new structures designed under the specification, plan drawings which denote the depth of anticipated scour. When the results of the Level One analysis indicate that stream instability or scour problems exist then a Level Two analysis should be performed or the POA developed in a manner that will mitigate any safety concerns during a flood or high flow event. Bridge owners must refer to the MDOT Drainage Manual for Michigan specific guidelines for scour evaluations.

6.04 Examining Scour during Routine NBI Inspection

Scour inspections during regularly scheduled NBI inspections consist of inspecting the entire channel within the vicinity of the structure for aggradation, degradation, general scour, and local scour. Defects

should be recorded on the Bridge Safety Inspection Report (BSIR) and used to influence the condition rating.

Since aggradation and degradation usually occur over a significant period of time verification is usually accomplished through periodic recording of stream-bed cross sections to determine overall changes in channel elevations. These types of scour may be caused by naturally occurring environmental changes, or from human induced modifications upstream or downstream from the bridge. For example, increased deforestation and agricultural land use upstream of the structure may lead to additional sediment laden runoff being deposited into the channel leading to aggradation.

General and local scour may occur suddenly through flow increases during, or immediately following, abnormal precipitation or catastrophic events such as a dam failure. Examination of the channel and substructure units for scour must occur during each regularly scheduled routine NBI inspection for all bridges over waterways. The evaluation may consist of visual observations to detect changes in the channel for bridges without substructure units in the waterway. For this condition the channel should be inspected for steep eroding banks, tension cracking, sloughing, meandering bends, and active undercutting.

When piers or abutments have submerged surfaces in less than 10 feet of water the wade and probe or boat and probe methods must be employed. Probing is important to detect whether the footing is exposed, undermined, or whether live-bed scour has caused loose sediment to refill the void. Where water depths exceed 10 feet an underwater diving inspection must be scheduled at intervals that do not exceed 60 months. When the results of the underwater diving inspection indicate that active scour is present that may potentially threaten stability, the frequency of underwater diving inspections should be increased (See Guidelines for Bridge Inspection Frequencies for more details). Additionally, efforts should be made during the routine inspection to detect changes through the performance of depth soundings to detect scour. The POA should also be tailored for these structures to ensure monitoring is performed during high flow events.

When scour countermeasures have been installed they must be inspected for deterioration and effectiveness. Improperly placed or inadequately sized materials will become unstable and may not offer the protection desired. Document scour or defects identified for any kind of scour countermeasure under the Abutment (BSIR #13) or Pier (BSIR #14) substructure item during the routine inspection, and on the Scour Action Inspection Report within the POA following an event that triggered monitoring.

Riprap should be angular interlocking stone or in unique situations can include fieldstone. Plain riprap should have a minimum size of approximately 8 to 12 inches and heavy riprap 12 to 24 inches. The protected area should be well graded. Signs of displaced stones, slumping, disintegration, and exposed or damaged geotextile filter can limit the effectiveness of the countermeasure.

Channel armoring should be well keyed to prevent washouts from occurring. Inspect surfaces for cracking and bowing. Where weep holes have been installed to equalize pressure verify that they are clean and functioning adequately. Sound any areas where undermining is suspected to determine if fill is missing from underneath.

Articulating concrete blocks (ACB) are preformed units which either interlock, are held together by cables, or both to form a continuous blanket or block matrix. ACB should be placed flat or sloped uniformly. Review the entire surface for missing or severely damaged blocks. Inspect the individual sections for overturning, uplift, cracking, and exposed or damaged geotextile fabric.

Gabion mattresses are basket or compartmented rectangular containers made of wire mesh filled with cobbles or other rock. Gabions should be inspected for movement and separation. The wire should be checked for abrasion and corrosion to ensure it is suitable to retain the rock. Inspect individual sections for undermining or sagging.

Grout filled bags are fabric bags that have been filled with grout to provide scour protection. Grout filled bags should be inspected to ensure that they are keyed in along each edge. Sound any areas where undermining is suspected to determine if fill is missing from underneath.

Sheet piling that has been installed as a scour countermeasure should be inspected for corrosion or section loss that could affect performance. Inspect the alignment for signs of tilting caused by inadequate toe, scour, or deteriorated tie-back anchors.

6.05 Scour Examination during Michigan Bridge Element Inspection

Element level information shall be collected during each inspection where scour protection is employed using the Michigan Bridge Element Inspection Manual. The inspection team leader shall document the scour protection that is visible, and use Condition State Table 10 to determine the relative effectiveness of the materials. Scour Protection that have been identified on the previous Underwater Diving Inspection Report shall also be entered on the Michigan Element Inspection Report with quantities based according to the information described in the report. The overall goal of collecting scour protection information is to determine the amount deployed at each site and to render an overall judgment relating to its effectiveness and stability.

6.06 Scour Critical Bridge – High Flow Event

It is often too dangerous to perform a scour inspection using probing or underwater diving techniques during or immediately following a storm event when the water elevation and flow levels are high. However, the site should still be safe to monitor from the deck surface if overtopping of the bridge has not occurred. The bridge owner or an inspection team leader should review the effects of the increased water velocities and look for signs that in adversely affect the structure. Repetitive site visitations should be scheduled as-needed until a scour inspection may be performed once levels return near normal.

Field reviews should be documented on the High Flow Event Report, which may be accessed within each bridge-specific POA. This is the only method to verify that that monitoring occurred. Fields within the High Flow Event Report include information for the storm duration, total rainfall, freeboard, and estimated flow rate. Additionally, the inspector may note observations including whirlpools, debris accumulation, and describe any actions that were taken. When settlement, pressure flow, or other

conditions warrant closure of the structure the bridge owner shall be immediately notified and MDOT Bridge Field Services shall be contacted as described in Chapter 10, Critical Findings.

Scour critical structures that have had active flooding will be evaluated annually to ensure that monitoring occurred through documentation of a High Flow Event Report. This information is necessary to ensure compliance with NBIP Metric #18 is achieved.

6.07 Scour Critical Bridge – Scour Inspection

Once conditions are safe to access the waterway following a high flow event, a Scour Action Inspection should be performed to record any contraction or local scour that occurred during the flooding. At a minimum, this should include probing around all substructure units that were submerged to determine if changes in the streambed or footing exposure occurred. Where water depths exceed 10 feet and depth soundings indicate that scouring occurred it is highly recommended to enlist a qualified diving inspector or perform a detailed bathymetric survey to determine the extent of damage. When previously unrecorded footing exposure or undermining is identified the bridge owner should be notified immediately.

6.08 Stream-Bed Cross Sections

Scour critical bridges with active erosion or observed scour should have cross sections recorded every two years or after a flood event where the scour POA was reviewed and monitoring occurred. For scour critical bridges without active erosion or observed scour the cross sections should be performed every four years or after a flood event where the scour POA was reviewed and monitoring occurred. Bridges with minor observed scour or erosion must have a minimum of one cross section in the file; including additional cross sections as changes in the channel are observed and every 60 months for locations requiring underwater diving. For structures over water without substructures in the water and no channel erosion a minimum of one cross-section must be in the file with additional ones as changes occur. These recommendations are also provided in the MDOT *Guidelines* for Bridge Inspection Frequencies and reiterated in Chapter 5 for the inspection team leader.

6.09 Scour Plan of Action

The Scour POA is required for all bridges where Item 113 is coded ≤ 3 or U (Unknown Foundation). For additional guidance for structures with unknown types of foundations see FHWA Memorandum HIBT-20 "Frequently Asked Questions – Bridges Over Waterways with Unknown Foundation". The MDOT POA form has been developed in MIB^{RIDG}E and all scour critical bridges shall have valid information entered into the database using the web-based application. The bridge owner may assign rights for the form to be updated by any active registered user when changes or monitoring are necessary.

The standard Information Summary and Current Status header displayed for other reports also appears for the Scour POA. The information within this section provides several key characteristics including location, dimensions, and design type, among other inventory and appraisal data. The scour evaluation code for Item 113 is also displayed which should be verified prior to creating or modifying an existing POA

(see Figure 6.09.01). If the coding is incorrect the inspection team leader may correct the value based according to the Level 1 analysis, information obtained on the plans, or field observations if the bridge owner concurs.

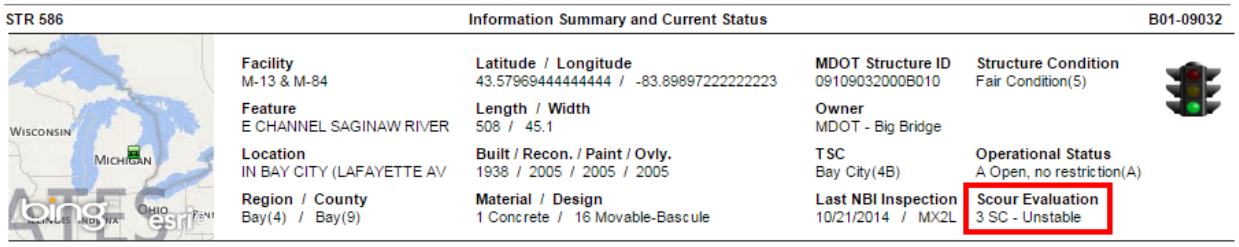


Figure 6.09.01 Information Summary and Current Status

Once the bridge owner or individual assigned with creating or modifying the POA selects the Scour Action Plan folder on the left navigation column and selects “Add New” or “Edit” they may begin adding detailed information. For POAs where editing occurs their name, organization, and the date will automatically populate once the form is saved. Unless a note or description is provided elsewhere on the form, the person identified is ultimately responsible for preparing the POA. When information is added to the form on behalf of another person or organization it should be noted in the Scour Evaluation Report – Executive Summary field. The Executive Summary field is also for general or specific information that summarizes the completed evaluation. After all of the necessary steps within the POA are added a check box to confirm the POA is complete should be selected prior to saving the information (see Figure 6.09.02).

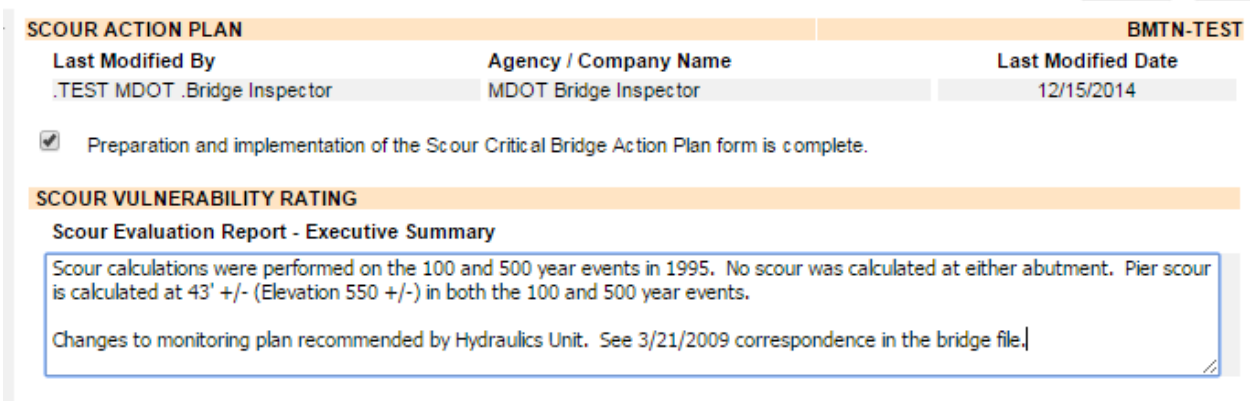


Figure 6.09.02 Information Summary and Current Status

The next section of the POA provides general information regarding foundation type and soil for each abutment (see Figure 6.09.03). During the analysis this information should be reviewed in the structural drawings and boring logs of the as-built plans. Locations of piers that will have submerged surfaces during a 100 year storm event should be indicated in the appropriate foundation type field which includes spread footing, pile (deep foundation), and unknown. Check boxes are provided to supply additional information regarding the soil types. A Comments field allows the author flexibility to record additional information

that could not be captured in the predefined fields. If the subsurface soil information fluctuates dramatically between the substructure units the variance should be described in this field.

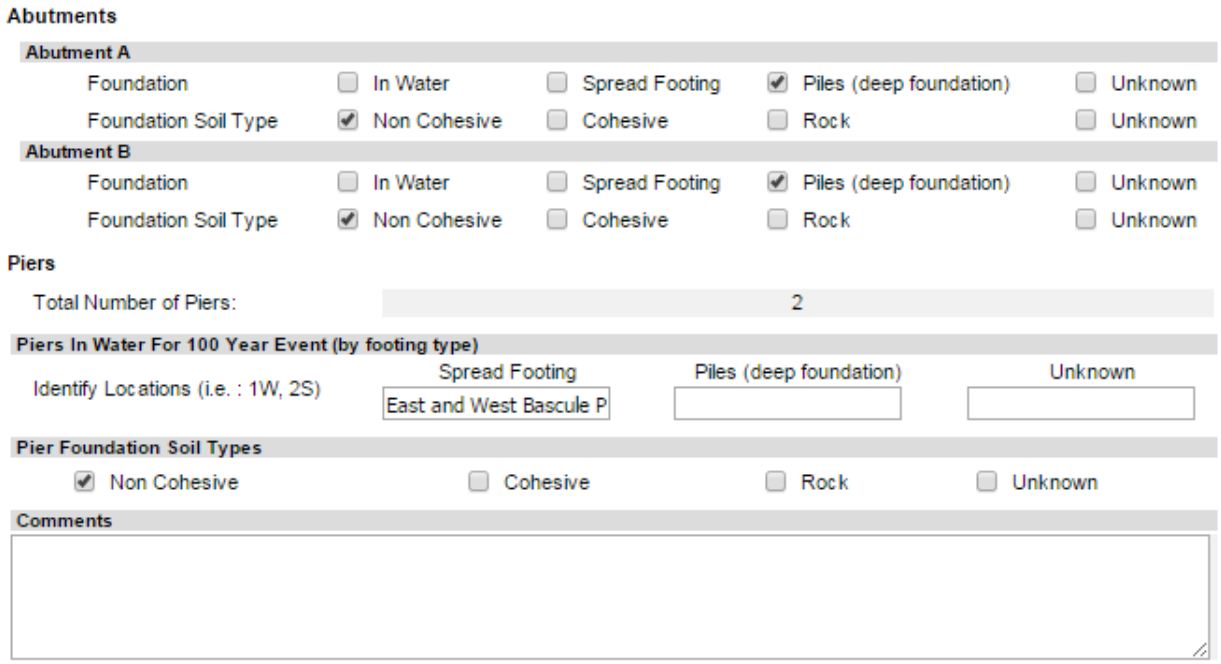
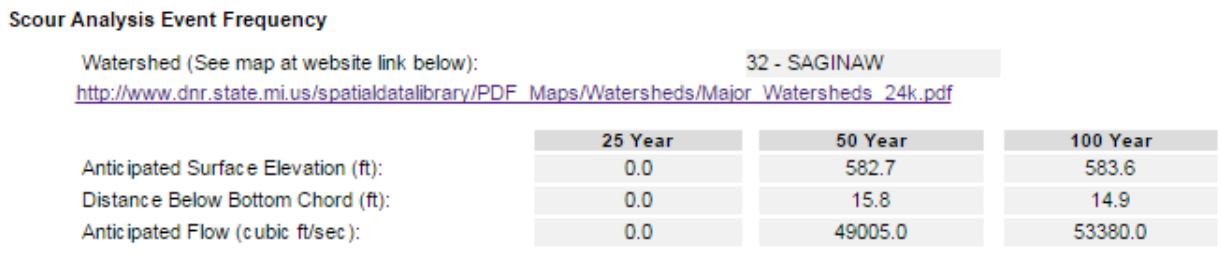


Figure 6.09.03 Foundation and Soil Type

The Scour Analysis Event Frequency allows the user to enter the appropriate watershed code from the provided map link of Michigan's Major Watersheds. Within this section the user may enter the anticipated surface elevation, distance below bottom chord, and anticipated flow for 25 year, 50 year, and 100 year events. This area provides those monitoring the structure during flooding reference data for the amount of freeboard, if any, during each event (see Figure 6.09.04).



	25 Year	50 Year	100 Year
Anticipated Surface Elevation (ft):	0.0	582.7	583.6
Distance Below Bottom Chord (ft):	0.0	15.8	14.9
Anticipated Flow (cubic ft/sec):	0.0	49005.0	53380.0

Figure 6.09.04 Scour Analysis Event Frequency

Commentary regarding the most vulnerable locations and where monitoring should commence will allow for efficient response and aid personnel responding to the site during inclement weather conditions. This information should be included in the Items to Watch comment field (see Figure 6.05.05). When the

results of probing or underwater diving indicate active scour is occurring at additional locations or the degree of which has increased the POA should be referenced and modified to include those areas.

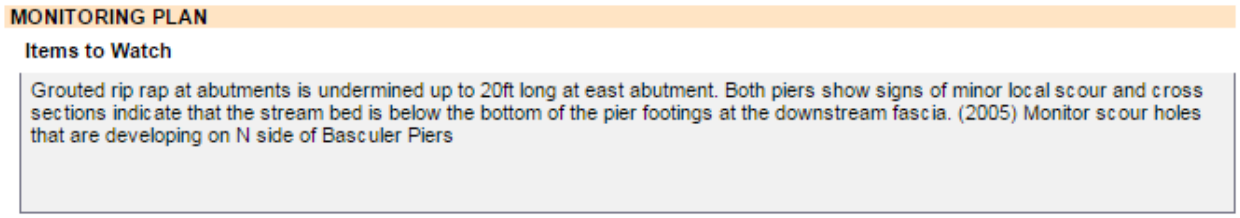


Figure 6.05.05 Monitoring Plan Items to Watch

Each time stream-bed cross sections are recorded the POA should be updated to reflect the most current date (see Figure 6.05.06). The frequency for performing the measurements may also be recommended by the bridge owner or inspection team leader based according to comparisons made between the previous one(s). When changes develop that cause concern the frequency should be increased to verify that scouring of the channel bottom will not affect stability.

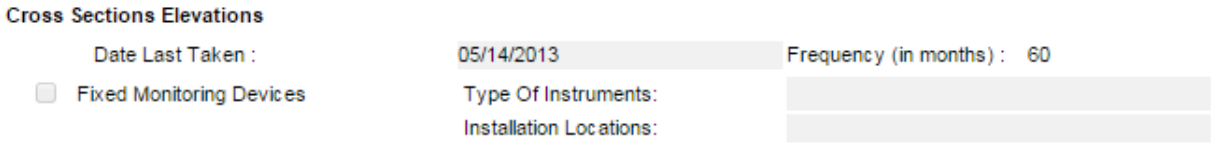


Figure 6.05.06 Cross Section Elevations

The agency responsible for ensuring that monitoring is performed must be provided on the POA (see Figure 6.05.07). In most cases this will include the name of the agency which owns the bridge, unless an agreement is in-place to have monitoring performed by another organization or larger unit of local government. The name, location, and current contact information shall be provided.

Figure 6.05.07 Agency Responsible for Monitoring

The FHWA defines three types of countermeasures including monitoring, hydraulic, and structural which should be considered for each scour critical bridge. The decision of when monitoring begins should be determined by a culmination of information including previously recorded scour data, the degree of flooding, existing hydraulic or structural countermeasures installed, and additional bridge specific factors. The POA template has several predefined triggers listed which encompass minimum conditions to begin the monitoring process (see Figure 6.05.08). These are recommendations to make the bridge owner aware of circumstances which may require field observations to begin. The bridge owner shall ultimately determine when monitoring must occur during a flood event.

Initiate Monitoring when a flood Warning is issued and/or when one or more of the following occurs

1. Structure will expereience 25 year peak flow or more
2. Structure is expected to have pressure flow
3. History of whirlpools upstream or adjacent to substructure
4. History of debris accumulation
5. Known or existing scour holes

Figure 6.05.08 Agency Responsible for Monitoring

The conditions to evaluate bridge closure, and a contact person to initiate the process, must be identified on the POA. Several predefined circumstances that frequently cause closure have been identified on the template. In addition, the bridge owner's name and contact information must be listed for re-opening the bridge after inspection (see Figure 6.05.09).

Conditions To Evaluate Bridge Closure

1. ☐ Pressure Flow(water source above bottom chord)
2. ☑ Observed whirlpools adjacent to substructure
3. ☑ High Debris Accumulation
4. ☑ Settlement of abutment/piers
5. ☑ Erosion of Road Way Embankment
6. ☐ Other

Contact People for Bridge Closure

Contact Name	Contact Title	Work Phone	Cell Phone	Remove
John Doe	Maintenance Coordinator	517-242-3232	517-242-3232	remove

[Changes to title or phone numbers are not saved until the 'Save' button is pressed]

Add Contact

[For NHS Bridges notify FHWA if closure is more than eight hours]

Contact for Re-Opening after Inspection (Bridge Owner)

Contact Name	Work Number	Cell Number
John Doe, P.E.	517-242-3232	517-242-3232

Figure 6.05.09 Conditions for Bridge Closure and Contact Information for Closing/Opening

Potential detours that may be used if closure of the bridge is necessary should also be provided. Any bridges along the detour route should be identified along with information that includes load restrictions and the scour criticality rating. This will aid bridge maintenance crews or vendors during the installation of appropriate signing once closure is recommended (see Figure 6.05.10).

Detour Route

Possible Detour Route(Max 1000 chars allowed):

M13 North to M-25 to M-84

Bridges/Culverts on Detour Route

Detour Strc#	Facility Carried/Feature Intersected	Load Limitations	Scour Rating	Remove
646	SAGINAW RI & MECHELEN DR		3	remove
669	US-10		N	remove
719	DUTCH CREEK		U	remove
645	M-13 CONN SB		N	remove
747	SAGINAW RIVER AND MCRR		3	remove

Figure 6.05.10 Detour Route Information